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Environmental Effects of Dredging Technical Notes

Alternative Dredging Equipment and Operational Methods to Minimize Sea Turtle Mortalities

Purpose

This technical note provides guidance on dredging and management alternatives for channel dredging projects to minimize adverse effects on sea turtles.

Background

Certain coastal channels are known to have high sea turtle densities. These turtles potentially can be adversely affected when these channels require dredging. However, operational practices and equipment modifications can be implemented to minimize injury to and mortality of these unique animals. Sea turtle mortalities from dredging operations have been dramatically reduced since the first reported incidents at Cape Canaveral ship channel in 1980.

The sea turtle species potentially affected by dredging are loggerhead (*Caretta caretta*), green (*Chelonia mydas*), and Kemp's ridley (*Lepidochelys kempi*). All three species are listed on the Federal Threatened and Endangered Species List. Kemp's ridley is of additional concern since its numbers have had a precipitous decline over the past forty years. Because of their population status, mitigation or compensation for their loss is generally not acceptable by National Marine Fisheries Service under the Endangered Species Act.

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Additional Information or Questions

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Introduction

Five species of sea turtles occur along the United States coastlines and are listed as threatened or endangered. The loggerhead sea turtle (*Caretta caretta*) is listed as threatened, while the Kemp's ridley (*Lepidochelys kempi*), the hawksbill (*Eretmochelys imbricata*), and the leatherback (*Dermochelys coriacea*) are all less abundant and listed as endangered. Florida "breeding populations" of the green sea turtle (*Chelonia mydas*) are listed as endangered, but green turtles in other US waters are considered threatened. The National Marine Fisheries Service (NMFS) has determined, based on the best available information, that because of their life cycle and behavioral patterns only the loggerhead, the green, and the Kemp's ridley are put at risk by hopper dredging activities (Studt 1987).

Sea Turtle Life History and Channel Habitat

The greatest portion of a sea turtle's life is spent in ocean and estuarine waters (Nelson 1988). After reaching the water, most hatchlings become pelagic, drifting inhabitants, spending a number of years in the gyres and eddies of the main Gulf Stream system of the Atlantic Ocean (Hopkins and Richardson 1984, Carr 1986). Subadult turtles inhabit bays and estuaries from April through October in Georgia and South Carolina and year-round in Florida (Hopkins and Richardson 1984). Adult turtles seem to prefer shallow coastal waters (Carr 1952, Rabalais and Rabalais 1980). Sea turtles generally migrate from northern climates to the warmer south during the fall and winter.

Sea turtles are generally omnivorous, but adult green turtles eat primarily aquatic vegetation (sea grasses). Their body temperatures are usually close to that of the surrounding water. Cold water temperatures may slow their body activity and a sudden change below certain temperatures may stun them and cause death.

Surveys and radio tracking studies indicate that sea turtles are attracted to and seek refuge at the Cape Canaveral entrance channel, especially during the winter (Butler, Nelson, and Henwood 1987). The Canaveral channel is also unique in that it contains one of the largest known aggregations of subadult loggerhead turtles in the world (Richardson 1990).

The activities of sea turtles in aquatic habitats are virtually unknown, particularly for ship channel habitats. Sea turtles are found in channels year-round, but appear to be more abundant in the warmer months. While turtles have been observed in channel areas along the Gulf Coast and East Coast of the United States, the highest concentrations are found in Florida. Mortalities or injuries of sea turtles from dredging have been documented primarily in only two channels--Cape Canaveral Harbor, Florida, and King's Bay, Georgia. These incidents appear to occur only on hopper dredges, since no incidents have been reported for other types of dredges. The lack of reported impacts on turtles in channels other than King's Bay and Cape Canaveral has been attributed to the lack of turtle monitoring during dredging and to the lack of an observed impact in other channels.

However, this could also be as a result of a lack of turtle occurrences in the channels during the time of dredging.

Other aspects of sea turtle life history are important to their management in channels. Kemp's ridleys, which have declined from tens of thousands to a few hundred, are on the verge of extinction (Fontaine and others 1985). Any further loss of this species may jeopardize its existence. Loggerheads and green turtles have much larger population numbers. Estimating their absolute abundance, however, is hampered by their oceanic existence. The age at which female turtles first nest is estimated to be between 15 and 30 years (Nelson 1988). Female adults deserve the greatest degree of protection since they take such a long time to mature and are the reproductive base of the population. Females should be protected especially in the spring and summer, when eggs are laid.

History of Dredging Effects on Sea Turtles

Before the 1980 maintenance dredging of the Cape Canaveral, Florida, entrance channel, sea turtle mortalities were not an issue during dredging operations. During the 1980 maintenance dredging of the Cape Canaveral entrance channel, an unusually large number of sea turtles were discovered in the channel and sea turtle mortalities from dredging activities were also documented.* The presence of large numbers of sea turtles in the channel was reported by shrimpers who had incidentally trawled up the turtles in a torpid condition during the two unusually cold winters prior to the 1980 maintenance dredging (Joyce 1982). Most of the turtles were loggerheads, but greens and Kemp's ridleys were also found.

A Sea Turtle/Dredging Task Force was formally established by the US Army Engineer District, Jacksonville in May 1981 to address the issues of sea turtle mortalities from dredges and maintaining a navigable channel for commercial interests and national defense. The task force is comprised of representatives from the NMFS, US Fish and Wildlife Service, Florida Department of Natural Resources, US Navy, university representatives, and the US Army Corps of Engineers. As a result of alternative dredging equipment, operations, and management techniques recommended by the task force and others, the documented numbers of turtles affected by dredging at Cape Canaveral entrance channel have been reduced from 71 in 1980 to 3 in 1981, 9 in 1984, 5 in 1986, 28 in 1988, and 7 in 1989. The 1988 channel maintenance removed the largest number of cubic yards of dredged material (approximately 1.5 million cu yd) since 1980 and had a much lower estimated turtle mortality than 1980.

The incidental take of sea turtles during dredging operations has been documented in the Cape Canaveral ship channel since the first study conducted in 1980 and King's Bay, Georgia, ship channel since its construction in 1988. During the ten-year dredging period from 1980 to 1990, 149 incidents with three species of sea turtle (loggerhead, green, and Kemp's ridley) have been reported from Cape

* P. W. Raymond. 1980. "Marine Turtle Observations aboard Dredge *Long Island*, Port Canaveral, Florida, 19 July - 1 August 1980," unpublished report to the National Marine Fisheries Service, St. Petersburg, FL.

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Canaveral and King's Bay entrance channels. This included 123 incidents at Canaveral and 26 incidents in King's Bay channel. Reported incidents have been limited to hopper dredges.

Table 1 shows the documented incidence of sea turtle mortalities since the 1980 dredging at Cape Canaveral entrance channel. The overall apparent reduction in sea turtle incidents may have been attributed to the alternative equipment tested and changes in operational procedures during dredging projects. The fluctuations in numbers of incidents may also be a reflection of seasonal and annual fluctuations in the sea turtle populations.

Table 1

Reported Sea Turtle Entrainment Incidents by Species during Dredging Activities from 1980 to 1990

Year	*Caretta caretta*	*Chelonia mydas*	Unidentified*	Total
		Cape Canaveral Entrance Channel, Florida		
1980	50	3	18	71
1981	1	1	1	3
1984/85	3	0	6	9
1986	5	0	0	5
1988	8	2	18	28
1989/90	0	6	1	7
Totals	67	12	44	123
		King's Bay Entrance Channel, Georgia/Florida		
1987/88**	7	1	1	9
1988	3	0	2	7†
1989	9	0	1	10
Totals	19	1	4	26

*Fragments of sea turtle carcasses not identified to species. It is assumed that most are *Caretta caretta*.

**Initial construction dredging for Trident submarine base.

†This number includes two *Lepidochelys kempi* caught in 1988 at King's Bay, Georgia.

The physical properties of the channels that attract the turtles to these habitat are also unknown. The channels were "created" by dredging and thus may not be considered natural habitats. The channels have water depths greater than the surrounding areas to accommodate ship traffic. The channels vary in depth from

12 to 50 ft and have substrates that vary from sand to silt to mud. Data on the physical properties of the channels have not been examined to see if relationships with turtle presence or absence can be established.

Because sea turtles are pelagic and very mobile, little is known about their life history once they leave a nesting beach. Most information about their activities in the Canaveral channel and other channels is based on hypotheses with very little data to substantiate or disclaim them. Time and space density patterns of turtles in the channels are unknown. Data are difficult to obtain in Canaveral Channel because the water is turbid and the bottom has a suspended, flocculent silt layer 6 ft or more deep. The turtles may be in the channel for various reasons. The presence of an abundant food supply may be attracting them. They may migrate into the area from cooler northern weather conditions. Sea turtles have been found covered with mud in a dormant state (Carr, Ogren, and McVea 1980). They may bury in the mud of the channel to cleanse their exteriors of parasites or for protection against colder environmental conditions. How the turtles are impinged by the dredge is also unclear. However, it appears that the turtles which are on or in the bottom are run over by the draghead and then sucked up into the hopper. Examination of flow patterns around the draghead suggests that it is unlikely a turtle will be sucked in from the sides unless it is very close.

Summary of Dredging Alternatives and Modifications

Operation Modification

Seasonal Restriction. Restricting dredging to a season when turtles are least abundant or least likely to be affected was one of many alternatives that has been implemented. The NMFS designated September through November as the best time for dredging based on the turtle's seasonal density trends and the presence of gravid females during the summer nesting season (Henwood 1990). The winter months were excluded due to the presence of higher numbers of turtles migrating into the area from colder more northern climates. In addition, the cooler water temperatures during the winter months may cause turtles to be in a more inactive state and more susceptible to impacts. The spring and summer months were excluded because this is the breeding and nesting season for turtles and protecting nesting females is a high priority. Kemp's ridleys are present during the late winter and early spring.

Draghead Pumps Turned Off. An additional operational procedure implemented in 1985 was the turning off of the pumps when the dragarm was raised and lowered. This was to reduce the potential of entraining turtles in the water column as the draghead was being raised or lowered.

Reduced Vessel Speed. During the 1989-1990 maintenance dredging at Cape Canaveral with the *McFarland*, the dredge operating speed was reduced from 2-3 knots to approximately 1 knot. Although the reduction in the speed of operation may potentially provide more time for a turtle to react to the oncoming draghead, its effectiveness relies on the animal's ability to respond to the oncoming

draghead. The turtle's response is difficult to evaluate; therefore, the effectiveness of this operation modification is unclear.

Dredge Type

Because of a high energy wave climate and a flocculent silt and sand material, hopper dredges were determined to be the safest and most efficient dredge to use in Canaveral channel. Clamshell dredges have been used in the channel on two occasions and did not result in any documented turtle mortalities. However, the required dredging depth could not be achieved. A hydraulic pipeline dredge is another potential option that may be used in the Canaveral Channel. However, the operation of the pipeline dredge will be limited to seasons when the sea conditions are calmer (Hrabovsky 1990). The relatively slow dredging motion of clamshell and pipeline dredges would likely further reduce turtle mortalities. The ability of these dredge types to provide the required depth in a timely fashion and at a cost comparable to other methods has been studied, but use of these dredge types does not appear to be economically or logistically feasible.

If the effects on sea turtles are time dependent, that is, longer dredging time results in more turtles being affected, then dredging by the most efficient means would reduce mortalities. Using larger hopper dredges and more dredges would shorten the time period of the dredge in the channel. This potential management alternative requires further investigation.

Draghead Type

Changing the type of draghead used on the hopper dredge may have been the most effective operational change used for reducing turtle mortalities. An IHC draghead was used during the Canaveral maintenance dredging in 1980, but subsequent dredging used the California-style draghead. The design and upright positioning of the IHC draghead causes its suction opening to act like a scoop, while the California-style draghead sits level in the sediment and may be less likely to entrain turtles (Studt 1987).

The number of potential variables (that is, dredge size, speed, and temporal differences) makes equipment difficult to evaluate. In addition, turtle mortalities were not effectively evaluated because screen sampling techniques were not consistent throughout. Dredging operation procedures should be considered when evaluating the types of dragheads versus numbers of turtles killed. Comparisons of dragheads alone cannot be validly used without evaluations of the methods and procedures used to operate each draghead. These procedures differ among ships and personnel.

The intake grating of the draghead was reduced to 12-in. openings from 1980 to 1987. However, it was decided in 1988 that reducing the size of the opening in the draghead probably did not reduce turtle mortalities. In addition, reducing the size of the grate openings attached to the bottom of the draghead may affect the ability to assess the number of turtles taken since turtles impacted by the draghead may be prevented from entering the hopper and not counted by observers.

Deflectors for Draghead

Rigid Deflector Design. A "cow-catcher" type turtle deflector was installed on the draghead and tested on the Corp's dredge *McFarland* in 1981. The deflector was constructed using 1/2-in. steel plate in a V-shape and attached in front of the draghead with 2-in. anchor chain. The deflector was designed to pivot with the movement of the draghead. This deflector was crushed in a matter of minutes.

In 1988, two new conceptual designs for deflectors were selected for testing during the Cape Canaveral maintenance dredging. One design was for a rigid deflector made of steel plates welded to the front of the draghead in a parallel V-shape pattern. Plates 1/2 in. thick were spaced 10 in. apart and varied in height from 24 to 43 in. high. The bottoms of the plates were 6 in. below the horizontal plane of the draghead when dredging at the 46-ft depth. This deflector was rendered inoperable due to the loss of plates within 3 days of its initial use. During this test two turtles were impinged between the plates of the deflector, resulting in their death.

Flexible Deflector Design. The second deflector tested during the 1988 Canaveral dredging was constructed of flexible 1/2-in. chain webbing forward of the draghead. This deflector was attached in a V-shaped configuration to the dragarm and draghead. A solid steel 12-in.-diameter shaft (ball) was installed at the lower forward end of the "V" to help the chain webbing maintain its shape in front of the draghead. This flexible deflector maintained its integrity during the one-week test and subsequent three weeks of dredging. One small turtle was taken by the dredge during 4 weeks of dredging. This turtle was small enough to fit through the chain webbing which may have contributed to its not being deflected. This flexible deflector showed promise of being effective in excluding turtles from the dredge. It maintained its integrity with a minimum of repair and did not affect production of the dredge.

The US Army Engineer Waterways Experiment Station (WES) Environmental Laboratory and Hydraulics Laboratory and the NMFS Mississippi Laboratory conducted tests of the deflector cooperatively in Panama City, Florida, during April 1989 on the *McFarland*. The objective of the tests was to monitor the area of suction influence around the draghead and the action of the flexible turtle deflector using divers and underwater video cameras. As a result of these tests, modified designs for the flexible turtle deflector were developed.

This modified flexible chain webbing turtle deflector was installed on both dragarms of the *McFarland* during the 1989-1990 maintenance dredging at Cape Canaveral, Florida, entrance channel. Installation of the deflectors and inflow screening was completed before dredging started. The turtle deflector tested was a flexible A-frame pipe structure designed to plow approximately 2 to 4 in. into the sediment ahead of the draghead. The heart of the system consisted of a solid steel shaft 10 in. in diameter and 4 ft long, which weighed approximately 1,000 lb and was attached by a cable sling noosed around the drag suction pipe. Attached by 1-in. shackles to the front of the steel bar were two triple-strength steel pipes forming the side legs of the bottom A-frame. Cross support braces made out of

4-in. triple-strength (schedule 120) pipe connected the side pipes to the solid support bar in the aft position. The side chain mesh was formed using 1/2-in. high test steel chain welded and bolted together to form the meshwork with 12-in. square openings. The side legs of the A-frame were attached to horizontal support plates welded to the draghead just above the heel pad on each side.

In order to deflect turtles, the deflector is required to ride on the ocean bottom. If the device is suspended in the water column, it will not deflect turtles to the side and would still allow turtles to go under the draghead. Since the deflector is attached to the dragarm, the positioning of the deflector is dependent on the angle of the dragarm. The turtle deflector was designed to work while the draghead was operating on the ocean bottom at a depth of 40 ft or less. If the draghead operates below the necessary 40-ft depth, the deflector would be pulled upward and off the ocean bottom.

The deflectors tested during the 1989-1990 Canaveral maintenance dredging required frequent repairs and were, therefore, ineffective for the duration of the dredging project. After observing the repeated destruction of the turtle deflectors, it was determined that the strength of future deflectors would need to be greatly increased.

Additional testing of the flexible turtle deflector design was done with draghead models at the Scripps Institute of Oceanography in San Diego, California. Numerous variations of deflector designs were tested under different conditions and evaluated according to efficiency in deflecting ability. The deflector models were attached to a plexiglass California-style draghead model. Underwater video photography was used to document the flow of material around the deflector devices and into the draghead to evaluate the deflector effectiveness.

Deflector tests investigated the ability to physically deflect the simulated (scaled 1/8) turtles out of the path of the dredge. Figure 1 shows the design which most effectively deflected the simulated turtles and best conformed to the sediment bottom. The sides of this design had a combination of chain and a solid metal bar. In all tests, the smallest simulated turtles (representing 11-in. turtles) were the most frequently taken by the draghead. These were small enough to go under the deflector in places which were raised off the sediment bottom. More turtles were found to be taken when the deflector shape became deformed or did not continually conform to the sediment bottom. This was seen when the deflectors were tested with a contoured or rough bottom.

Figure 1 is the deflector design which has the most potential for reducing turtle mortalities from California-style suction dragheads. Deflecting efficiency for all size classes of turtles depends on whether the deflector conforms to the contour of the sediment bottom at all times during dredging. Although this design effectively follows the bottom contour, incorrect installation of the deflector onto the draghead may prevent the deflector from correctly touching the sediment bottom. In model tests, the deflectors tested at 2.72 knots did not remain in continual contact with the sediment bottom as well as those tested at 0.9 knot. Frequently,

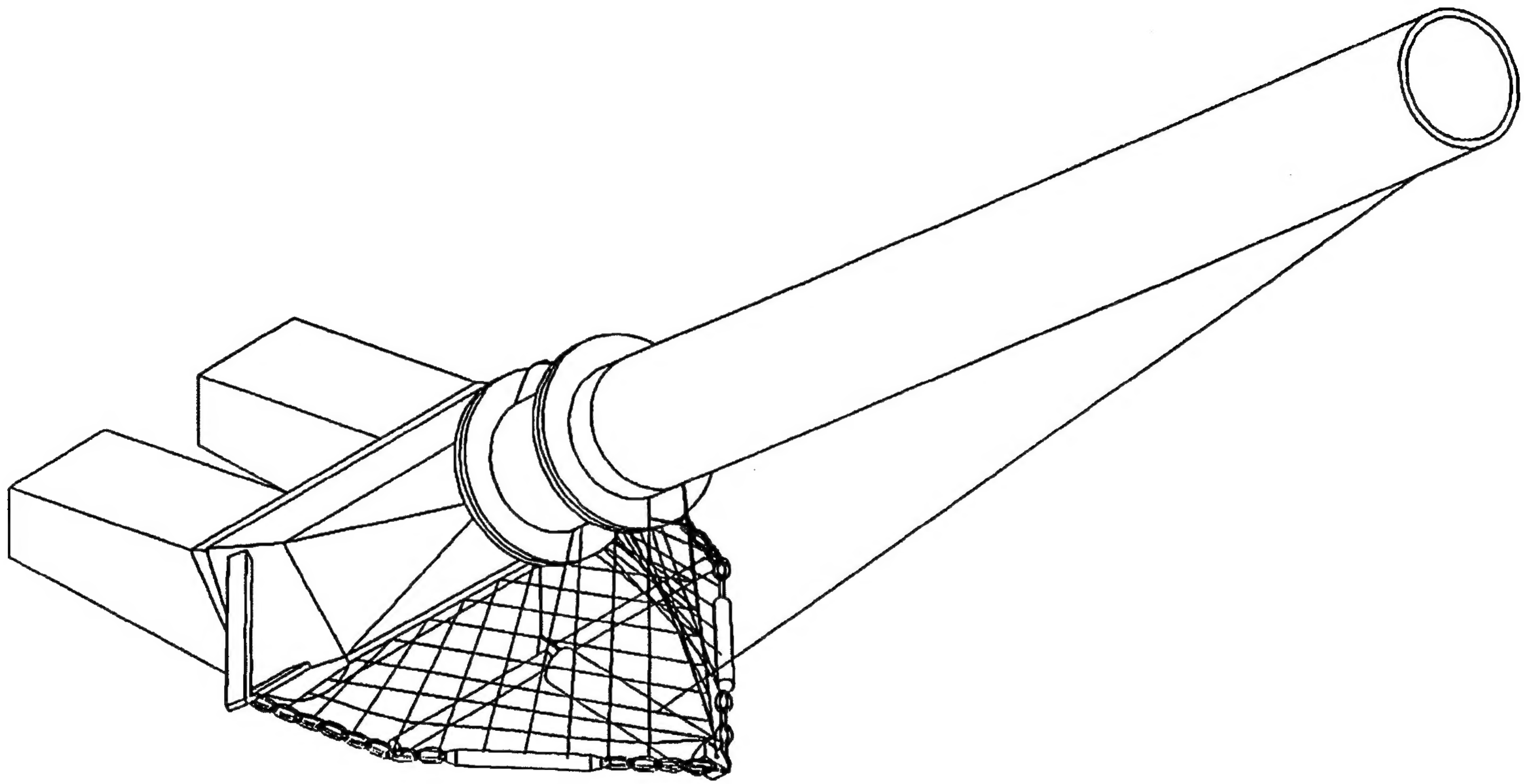

Figure 1. Deflector design having straight bottom frame sides with combined chain and bar; support cable attached to front and rear of center weight

fewer simulated turtles were deflected when the model dredge operated at 2.72 knots than at 0.9 knot. A slower operating speed may also give turtles more time to react to the deflecting device. A slower dredge operating speed and the deflector design shown in Figure 1 are suggested for testing during future hopper dredging projects in Cape Canaveral entrance channel when turtle deflectors are required.

Summary of Sea Turtle Management Alternatives

Relocating Turtles

A local shrimper was contracted during some Canaveral dredging projects to trawl ahead of the dredge to clear the channel of turtles and relocate them 5 miles down the coast to safety. However, the trawler could not work safely in front of the moving dredge because the trawler's nets would often bog down with large clay balls in the channel. This would spin the trawler around and subject it to a potential collision with the dredge. Trawling was then conducted at a greater distance ahead of the dredge. In the past, this proved to be ineffective because of the inability to move the large numbers of turtles found in the channel and those turtles which return to the channel once removed. However, recent observations suggest a decline in the number of turtles present in the channels.* Relocation of turtles out of the channel may be feasible when there are lower densities of turtles but requires additional investigation.

Although turtles may be present, trawlers cannot pull nets on the bottom inside jetties or nearshore because rocks or old pilings may snag and tear nets. Previous turtle trawling surveys were usually done from the jetties outward, which was less destructive to the nets than trawling inside.

Trawling should be done in the specific area where the dredge will be operating when it returns from the dump site. The dredge and trawler should work together to determine where the trawling should concentrate while the dredge is at the dump site. While the dredge is actually dredging, the trawler(s) could work in the surrounding areas or in an area historically known for high turtle densities.

Baiting of turtles away from the dredging site is another relocation option. It has been suggested that one reason turtles may be taken so frequently by shrimpers is that they are attracted to the fish and other bycatch which is thrown overboard. If turtles are attracted to bait, then they might be attracted away from the channel. However, whether the turtles will respond and in adequate numbers is not known.

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* A. Bolton and K. Bjorndal. 1988. "Survey of Sea Turtles in Cape Canaveral Channel," unpublished survey reports to the National Marine Fisheries Service, St. Petersburg, FL.

Dispersal of Turtles

Various techniques such as sonic pingers, tickler chains, bubblers, and electric currents have been suggested as methods to disperse turtles away from the dredging. However, it is not known if the turtles will respond to these stimuli or if the turtles can respond rapidly enough to elude a hopper dredge, particularly if the turtles are in a dormant or torpid condition.

Monitoring

Monitoring of Potential Dredging Impact

Each Corps District is required by the Endangered Species Act to conduct literature or biological surveys before every dredging project to document any endangered species occurrences in the area of dredging and determine the potential impacts related to the dredging activities. For some dredging projects, additional monitoring measures are required such as dredged material screening and endangered species observers.

Systematic trawling or aerial surveys are conducted in the channels before dredging. These surveys help determine the population status and distribution of the sea turtles in the channels over either a short or extended period of time. The information resulting from the present trawling and aerial methods is severely limited because of the behavior of the turtles and difficulty in locating the animals. These methods can only survey turtles which are in the water column or surfacing. Very little information can be collected about turtles on or in the bottom sediment, although these are the turtles most susceptible to being taken by the dredges.

Monitoring of Turtle Mortality

Endangered Species Observers. Recovery and documentation of sea turtle parts is a monitoring requirement. Accurate identification of these parts and detailed records are a vital part in the evaluation of dredging impacts and success of the turtle deflectors.

The Endangered Species Observer Program was established in 1980 and evolved through consultation between the NMFS and the US Army Corp of Engineers, as mandated by the Endangered Species Act. Endangered species observers are used during dredging projects whenever biological data suggest potential impacts on sea turtles. The observers work closely with the dredge crew to identify and record dredging incidents with endangered species. The observers hand sort all collected debris and record information on every dredging load. A reported sea turtle incident represents one sea turtle which was entrained either whole or in parts. Sampling for whole turtles and parts is done through observation and inspection of the hopper, the draghead, and screening of the intake structures or hopper overflow.

Material Screening. Because the material being pumped into the hopper dredge is a dark-colored mud-sand mixture, visually monitoring turtles taken into the hopper is difficult. To enhance the ability of observers to monitor sea turtle mortalities, screening of skimmers and overboard overflows has been required of hopper dredges in the Canaveral Channel. Because overflow screens primarily collect floating materials, estimates of turtle mortalities based on overflow screen collections may be low. In 1988, the WES Environmental Laboratory conducted tests to assess techniques for monitoring recovery of turtle parts on dredges. To obtain better estimates of sea turtle mortalities, tests were conducted on screening inflows during the 1988 dredging at Cape Canaveral. While the screening of inflows appears to be feasible, further investigations are needed to ensure their effectiveness and safe operation. The variability of internal discharge piping into the hopper inhibits a generic design to screen inflow. Additional considerations are the type of material being dredged and the safe retrieval of parts by the endangered species observers.

Monitoring the Effectiveness of the Management Program

The management program cannot be evaluated by monitoring turtle numbers or mortalities. The effectiveness of these protective measures is difficult to assess because of numerous operational differences among the 1980-1990 dredging projects. Screening of inflows may allow for more accurate assessment of turtle mortalities and the effectiveness of measures to reduce the mortalities. However, a reduction in sea turtle mortalities during dredging in the Cape Canaveral ship channel since 1980 may be attributed to dredging operational changes or possibly to a decrease in the local abundance of turtles.

This management plan can be evaluated by assessing whether the management practices used are the best available technology to reduce sea turtle mortality and injury to the least number possible. Evaluation of whether the best sea turtle life history information is being provided to implement the best management practices should also be considered. This evaluation should be conducted by a technical advisory group and recommendations provided to the agencies for implementation.

Summary and Conclusions

Substantial apparent reduction in sea turtle mortalities likely has resulted from modifications in dredging equipment and operational practices. These modifications were a result of recommendations from cooperative efforts by Federal and state agencies, universities, and the dredging industry. Another effective measure which has been implemented is the use of seasonal restrictions. Measures which are being tested and show potential for reducing turtle mortalities include the use of a flexible turtle deflector and alternative dredging equipment. The problems of dredging a flocculent silt material in high wave climates and the general lack of biological information on the turtle activities in channels make reducing turtle mortalities a difficult challenge.

A long-term requirement exists for the Corps to maintain channels for safe navigation and national defense and at the same time reduce turtle mortalities from dredging operations in channels. This can be best achieved through a long-term management plan that implements the best management practices using the best available dredging technology and sea turtle life history information.

References

Berry, S. A. 1990. "Canaveral Harbor Entrance Channel Operational Measures To Protect Sea Turtles," *Proceedings of the National Workshop on Methods to Minimize Dredging Impacts on Sea Turtles*, D. D. Dickerson and D. A. Nelson, Eds., Miscellaneous Paper EL-90-5, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Butler, R. W., Nelson, W. A., and Henwood, T. A. 1987. "A Trawl Survey Method for Estimating Loggerhead Turtle, *Caretta caretta*, Abundance in Five Eastern Florida Channels and Inlets," *Fishery Bulletin*, Vol 85, No. 3.

Carr, A. 1952. "Handbook of Turtles," Comstock Publishing Associates, Cornell University Press, Ithaca, NY.

____________. 1986. "Rips, FADS, and Little Loggerheads," *Bioscience*, Vol 36, pp 92-100.

Carr, A., Ogren, L., and McVea, C. 1980. "Apparent Hibernation by the Atlantic Loggerhead Turtle *Caretta caretta* off Cape Canaveral, Florida," *Biological Conservation*, Vol 19, No. 1, pp 7-14.

Fontaine, C., Marvin, K., Williams, T., Browning, W., Harris, R., Indelicato, K., Shattuck, G., and Sadler, R. 1985. "The Husbandry of Hatchling to Yearling Kemp's Ridley Sea Turtles (*Lepidochelys kempi*)," National Oceanic and Atmospheric Administration Technical Memorandum NMFS-SEFC-158.

Henwood, T. 1990. "An Overview of the Endangered Species Act of 1973, As Amended, and Its Application to Endangered Species/Dredging Conflicts in Port Canaveral, Florida," *Proceedings of the National Workshop on Methods to Minimize Dredging Impacts on Sea Turtles*, D. D. Dickerson and D. A. Nelson, Eds., Miscellaneous Paper EL-90-5, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Hopkins, S. R., and Richardson, J. I., Eds. 1984. "Recovery Plan for Marine Turtles," US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, St. Petersburg, FL.

Hrabovsky, L. 1990. "Hydraulic Cutterhead Pipeline Dredging," *Proceedings of the National Workshop on Methods to Minimize Dredging Impacts on Sea Turtles*, D. D. Dickerson and D. A. Nelson, Eds., Miscellaneous Paper EL-90-5, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Joyce, J. C. 1982. "Protecting Sea Turtles While Dredging," *The Military Engineer*, Vol 481, pp 282-285.

Nelson, D. A. 1988. "Life History and Environmental Requirements of Loggerhead Turtles," US Fish and Wildlife Service Biological Report 88(23), Washington, DC.

Rabalais, R. C., and Rabalais, N. N. 1980. "Occurrence of Sea Turtles on the South Texas Coast," *Contributions to Marine Science*, Vol 23, pp 123-129.

Richardson, J. 1990. "The Sea Turtles of the King's Bay Area and the Endangered Species Program Associated with Construction Dredging of the St. Marys Entrance Ship Channel," *Proceedings of the National Workshop on Methods to Minimize Dredging Impacts on Sea Turtles*, D. D. Dickerson and D. A. Nelson, Eds., Miscellaneous Paper EL-90-5, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Studt, J. E. 1987. "Amelioration of Maintenance Dredging Impacts on Sea Turtles, Canaveral Harbor, Florida," *Ecology of East Florida Sea Turtles*, Proceedings of Cape Canaveral, Florida Sea Turtle Workshop, Feb 26-27, 1985, W. N. Witzell, Ed., National Oceanic and Atmospheric Administration Technical Report NMFS 53, Miami, FL.